

**REDUCED RISK MANAGEMENT
OF INSECT PESTS IN SUGARBEETS**

CONTRACT NUMBER: 99-0254

PROJECT FINAL REPORT

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EXECUTIVE SUMMARY

The beet armyworm (*Spodoptera exigua*) has been identified as the most important sugarbeet pest in recent years. This pest reduces seedling density (stands), defoliates plants and feeds on the sugarbeet root. Presently, growers manage beet armyworm larvae with foliar applications of primarily chlorpyrifos (Lorsban®) and methomyl (Lannate®), which are susceptible to FQPA regulatory actions. The overall goal of this project is to demonstrate improved integrated management of insect pests through reduced application of insecticides and preservation of beneficial insects.

Earlier demonstrations were conducted at the U.C. Davis campus and in the south San Joaquin Valley and Imperial Valley. Beginning in 2001, sugarbeet production was concentrated in the South San Joaquin Valley (Merced County to Kern County) and the Imperial Valley due to beet factory closures at Tracy and Woodland, California, in December 2000.

The objectives of the sugarbeet PMA are: 1) to demonstrate reduced risk management of sugarbeet armyworm; and 2) to demonstrate improving sugarbeet stands and reducing pesticide use in the Imperial Valley.

A field scale trial using traditional and biorational techniques to manage beet armyworm was established in Fresno County. Two fields were utilized with about 30 acres in each field treated with biorational practices, and the standard practice was used on the remaining 60 acres of each field. The 60-acre plots were treated by traditional means (chlorpyrifos and methomyl), and the other 30 acres were monitored using pheromone trapping techniques and sprayed with reduced risk materials when beet armyworm larvae were most susceptible. Sweep netting was incorporated to monitor secondary pest problems and effects on beneficial populations between the traditional and reduced risk material applications. An integral part of this research was to provide growers and PCA's with an easy and effective method of monitoring target pests to optimize insecticide application. Effective monitoring facilitates treatment timing in the most efficacious manner.

Seedling protection in establishing stands in the harsh environment of the Imperial Valley is of paramount importance to growers. Traditional grower practice requires multiple insecticide treatments in establishing plant populations. These are both pre- and post-emergent. Strip trials were established to demonstrate seedling protection using grower preferred treatments and seed treated with an application of the reduced risk systemic insecticide imidacloprid (Gaucho®). Utilization of this seed treatment protects seedlings against certain pests that must otherwise be controlled by insecticide application.

The sugarbeet PMA successfully demonstrated that biorational control of beet armyworm has merit when coupled with improved, effective pest monitoring techniques. Success was achieved as well in alternative seedling protection through application of a reduced risk material as a seed treatment.

This strategy also indicated the potential for reduction of insecticide applications currently made under the preferred grower practice.

In conclusion, improved integrated management of beet armyworm in sugarbeets is warranted, and usable damage thresholds and monitoring techniques must be developed to achieve this goal. In addition more effective reduced risk materials must be used to aid in the development of this IPM program. Reduced risk systemic materials, applied as a seed treatment, demonstrate clearly the benefits of this strategy in both protection of seedlings and reduction of the number of pesticide applications necessary for crop establishment. More effective reduced risk materials may expand the scope of insect control, when used as a seed treatment, further enhancing environmental benefit.

Reduced Risk Management of Insect Pests in Sugarbeets

Objective 1: Demonstration of Reduced Risk Management of Sugarbeet Armyworm: L. Godfrey

Introduction. Beet armyworm (*Spodoptera exigua*) larvae remain a significant insect pest of sugarbeets in the Central Valley. The concentration of sugarbeets to the central/southern San Joaquin Valley and to the Imperial Valley has placed even added importance on managing this pest since these are the areas that traditionally have been impacted the most by lepidopterous larvae. This species has a wide host range and is a significant pest (in addition to sugarbeets) on tomatoes, cotton, cucurbits, alfalfa, lettuce, and other crops. Beet armyworm eggs are deposited in clusters of ~100 on the leaf surface. Egg masses are covered with hairlike scales. Newly-emerged larvae feed in a cluster initially and then move over the plant. The larvae skeletonize plant leaves leaving the veins. On sugarbeets, this defoliation can cause significant yield losses. In addition, in recent years the larvae appear to feed in more protected areas of the plant as opposed to populations in the 1970's and 80's. This has resulted in the larvae often feeding on the beet roots near the soil surface or slightly below the soil surface (larvae crawl into soil cracks caused by the roots) and in the crown of the plant instead of on the exposed leaves. This root feeding provides entry ports for root rotting organisms into the beet roots. These root rot diseases can quickly decimate a sugarbeet stand or nearly mature crop. Finally, beet armyworm larvae also inhibit sugarbeet seedling establishment by clipping emerging seedlings; this can result in inadequate stands and the need for replanting.

Control of beet armyworm infestations during the growing season is largely accomplished with applications of organophosphate and carbamate insecticides (primarily Lorsban® and Lannate®). Insecticide usage in the two counties with the most sugarbeet acres, Fresno and Imperial counties, showed the following trends from 1995 to 2000 (C-DPR PUR data). Insecticide use (pounds active ingredient applied per harvested acre and number of acre treatments) increased over this period in Fresno Co. from 1.5 and 1.8 (1995) to 2.8 and 3.6 (1999) for the pounds and number of application parameters, respectively (Table 1). Levels declined by ~1/3 in both cases in 2000. The largest increase was from the 1996 to 1997 seasons. The applications were ~50% Organophosphate from 1995 to 1997 and that percentage increased to ~60% in 1998 and 1999. This percentage fell to 51% in 2000. There has been a concomitant decline in the use of carbamates (~40% of the applications from 1995 to 1997 and down to ~30% from 1998 to 2000). The use of biologicals, although never very high, has also declined from a high of 7.4% of the applications in 1996 to 0.7% of the applications in 1998 (Table 1), but this value has increased back to 5.3% in 2000. Pyrethroid use has increased to 9.4% of the applications in 2000. Growers are hesitant to use pyrethroids because of the potential for flaring spider mite populations in sugarbeets; there are no miticides registered in sugarbeets. In Imperial Co., insecticide use on sugarbeets stayed fairly constant from 1995 to 1999 (Table 1). The pounds active ingredient applied per harvested acre has averaged 4.1 (range of 3.2 to 4.5) and the number of acre treatments has averaged 6.8 (range of 6.0 to 7.8). Usage declined in 2000 to 2.2 pounds active ingredient applied per harvested acre and 5.3 acre treatments. Use of organophosphate insecticides has declined from 1995 to 2000 from 75.1% to 64.2% of the applications. This decline was offset with an increase in the use of carbamates (11.7 up to 17.2% of the applications) but that also waned in 2000 to 13.1%. Pyrethroid usage is on the increase

partially due to availability of registrations; 13.2% of the applications in 1995 were pyrethroids under a Section 18 registration and this has increased to 20.4% of the application in 2000. The use of biological insecticides in Imperial Co. is negligible, but did double between 1999 and 2000 to 3.4%.

In recent years in the Central Valley, repeat applications of insecticides are often needed for acceptable BAW control and control has still been inadequate. These applications have eroded the profitability of sugarbeets and the lack of control has reduced the sucrose yields. In addition, the multiple applications have flared populations of secondary pests such as spider mites, leafhoppers, etc. In 2000, Alliance fields were heavily damaged by spider mites and *Empoasca* leafhoppers. Regardless of the treatment, the beets were nearly completely defoliated by about 1 month before harvest. When this occurs, the plants regrow, which utilizes stored energy that could go into sucrose at harvest, further compromising yield.

The susceptibility of new, high yielding sugarbeet varieties to beet armyworm defoliation has been questioned. These varieties have a unique genetic background compared with older varieties and have a different leaf architecture (heavier canopy). Preliminary studies conducted under funding from the California Beet Growers Association in 2001 showed no difference in the response to defoliation or the susceptibility to infestation. Suh (1980) evaluated the effects of defoliation on sugarbeet yield in the late 1970's. His results showed the plants were extremely resilient of damage and that acceptable yields could be produced in spite of severe (nearly 100% in some cases) defoliation. His studies, however, had many limitations and the results were never implemented or accepted by growers. Follow-up studies funded by the California Beet Growers Association in 2001 (a combination of studies with various BAW levels and with artificial defoliation) showed fundamentally similar results. The increased level of root rot associated with BAW infestation was documented, however, in the 2001 studies and this negatively impacted yields.

Parasitoids, *Hyposoter exigua*, predators, and virus diseases potentially inflict a high degree of natural control on beet armyworm populations. However, given the high BAW populations commonly seen and the need for quick knockdown of these outbreaks, these natural enemies have not been fully utilized in the Central Valley sugarbeet system. Our observations in 2000 and 2001 have also shown that virus diseases of BAW are quite prevalent.

The efficacy of the organophosphate insecticides appears to be waning probably because of the development of resistance (verified in vegetable systems). Small plot studies with California Beet Growers Association funding in 2001 showed that repeated applications of Lorsban® or Lannate® (3 applications at monthly intervals) actually flared BAW populations in late July and August. Regulatory actions, FQPA, water quality, and others, may also limit the use of these products. The development and use of adoptable thresholds would allow growers to lower insecticide use by maximizing the natural ability of sugarbeet plants to compensate for defoliation. Decreased insecticide use would in turn reduce the incidence of secondary pest outbreaks by not disrupting naturally occurring biological control organisms. Therefore, there is a need to design alternative, improved IPM programs for beet armyworms on sugarbeets in the central and southern San Joaquin Valley.

Materials and Methods

Work for this objective was conducted in Fresno Co.

Tasks 1 and 3.

A demonstration project was conducted in Fresno County to attempt to manage beet armyworms using biorational means in comparison with the standard grower practice. Two late fall/winter planted fields were utilized in which the biorational practices were used on 30 acres compared with the standard practices on the remaining ~60 acres in each field. The PCA was involved in making decisions on the grower-practice (conventional) side and the PMA project, in concert with the PCA, made management decisions on the biorational side. The concept for the biorational management was to use pheromone traps to monitor the beet armyworm moth flights and to make visual inspections of foliage for egg masses and small larvae. Sweep net samples and visual observations were used to sample larger larvae. The control tactic was to use B.t. sprays (Lepinox®) at the onset of egg hatch. This would concentrate the activity of B.t. onto the early instars, where it is most effective. The grower practice was to use applications, as needed, of conventional insecticide such as Lannate®, Lorsban®, or other organophosphate/carbamate insecticides, and Success® (a Section 18 registration) when applicable.

The following samples were collected on a weekly interval (irrigation and/or chemical treatments prevented sampling on a few dates).

- 1.) wing/sticky pheromone traps baited with BAW pheromone were placed in each field on 8 June.
- 2.) bucket pheromone traps baited with BAW pheromone were placed in each field on 8 June.
- 3.) sweep net samples were taken in each field (grower and biorational portions as soon as this segregation occurred), samples were taken to the laboratory and the following arthropods were counted: beet armyworm larvae, *Empoasca* leafhoppers, and beneficials (lygus bugs, stink bugs, minute pirate bugs, big-eyed bugs, assassin bugs, damsel bugs, lacewings, lady beetles, collops beetle, parasitic wasps, and spiders).
- 4.) visual inspections were done on 20 leaf samples in each field to assess the numbers of beet armyworm egg masses and larvae and percentage of leaves infested with spider mites
- 5.) defoliation ratings were made weekly on a 1-10 scale with 1 being no defoliation and 10 being complete defoliation
- 6.) harvest samples (from a commercial harvest) were collected in October from both fields and from the biorational side and the grower standard side; about 10 acres was harvested from each "plot"
- 7.) sucrose content was determined at the Spreckels tare laboratory and sucrose yields were calculated.

Results

Tasks 1 and 2.

Pheromone traps: Moth flight was equal to or higher than in 2000. Flight peaked at ~225 per night in mid-July and mid-August (Fig. 1). In 2000, flight peaked at ~200 per night. Trapping with the wing trap was discontinued in mid-season 2001 because of low trap captures. We suspect that birds were removing the moths from the sticky surface. Dust and captures of other insects are also drawbacks with this trap. There were three flight peaks during the “season” (one peak also occurred in April/May and another in late September) in 2001 (Fig. 1). It was interesting to note how much the flight varied over a fairly short distance. We were conducting research, funded by the California Beet Growers Association, on BAW impact on sugarbeet production (Task 2 of this project which was funded in 2000 but not funded for 2001) at the West Side Research and Extension Center (about 20 miles from these Alliance fields). BAW flight was also monitored at this site and the flight peaks were consistently about 7 days earlier than at these grower fields.

Research in cotton has shown that ~930 degree-days (882 for females and 977.9 for males) (54°F lower threshold) are needed for development of BAW from egg to adult. The developmental rate on sugarbeets is unknown (developmental rates can vary significantly among hosts). Using 1 June as the estimated initial date of oviposition, i.e., when the moths forming flight peak 1 started to fly, the second flight peak should start about 7 July. With the limitation of daily temperature data and weekly trap captures, this agrees well with the pheromone trap data. The next generation adults should appear on 11 Aug based on degree-day accumulation. However, the trap captures showed an increase in numbers starting in early August (actually numbers never approach zero between the second and third flight peaks). Therefore, the degree-day accumulation accurately predicted the timing of the second flight peak but did not perform well for predicting the third flight peak.

Field Treatments: Overall, BAW populations in 2001 were low. This was seen in this Fresno Co. area on cotton, alfalfa, tomatoes, sugarbeets, etc. The treatments as shown in Table 2 were applied to the biorationally managed and grower managed areas. In field 99, one Lepinox application was made in late June to “ward-off” the first BAW peak. Lorsban® was applied to the conventionally-managed side of the field at the same time. Although moth flights were high thereafter (mid-July and mid-August), we were satisfied with the low amount of defoliation and no further applications were made to the biorational side in this field. One additional application of Success® (a Section 18 registration) was made to the conventional side of this field in August, 2001. In the second field (field 96), populations of BAW were even lower. No applications were made to the biorational side and one Success® application was made to the conventional side in mid-August. An application was probably also needed for the biorational side in mid-August, but Success® would have been the material of choice. This would have negated any comparison so it was decided not to make any applications in this field to the biorational section.

Beet Armyworm Populations: BAW larval populations from each of the two fields are shown in Fig. 2 and 3 (leaf samples) and Fig. 4 and 5 (sweep samples). In field 99, treatments were applied in late

June in response to the increasing larval population (at least in the biorational side) as shown by the leaf samples. The sweep net samples did not show this increase because the population was mostly very small larvae and even some egg masses that resulted from the first moth flight; these stages are not sampled well with a sweep net. This timing was ideal for a Bt product and the population remained low and “stable” the rest of the growing season in the field/approach as shown in Fig. 2. The sweep net samples from this field showed similar results albeit somewhat more BAW pressure in mid-July. The late June application of Lorsban® in the conventional side appeared effective for larval control for 2+ weeks (most easily seen from the sweep net data [Fig. 4]). However, larval populations in mid-July and August appeared to be destabilized, potentially as a result of the June application of Lorsban®. About a week following the moth peak in early July and early August, larval populations in the conventional side were high. Populations were more mitigated in the biorational side during these same periods. Results were different in field 96 which was about 2 miles from field 99. Populations were overall much lower and there were no early-season worm populations, i.e., June and early July (Fig. 3 and 5). There was a population peak in late July (lower than in field 99) and another peak in mid-August. The Success® application in early August corresponded to the time when larval populations normally crash due to poor host quality, the cycling through of this August generation and/or the activity of virus diseases of the worms which was very high in 2001.

Beneficials: Sweep net samples from the biorationally-treated area and the grower-treated area in Field 99, 28 June and once treatments had been applied, showed a slightly higher number of beneficials in the biorational treatment (Fig. 6). There were generally from 50 to 100% more beneficials in this treatment approach than in the conventionally-treated side. In field 96, there were overall fewer natural enemies and populations varied greatly (Fig. 7). There were no trends for numbers in either of the two treatments.

Leafhoppers: Leafhopper populations built-up to significant levels in both treatments in field 99 (Fig. 8). Populations were at ~200 per 50 sweeps in late June (time of first applications). Populations followed similar patterns until mid-July when the levels in the conventional treatment spiked quickly and those in the biorational treatment continued a gradual increase. Populations in the biorational treatment reached a peak in early August followed by a precipitous decline (adults were likely emigrating out of the field). In the conventional side, the Success® application in early August appeared to reduce leafhopper populations by about 50% for a few day period, but they quickly built-up again. In field 96, there were actually more early-season leafhoppers than in field 99 and populations in July and August followed similar trends (Fig. 9). There was a 2-week crash in levels in the biorational side in early August. Leafhopper levels in the conventionally-managed treatment generally declined over the sample period. The Success® application provided some control and also basically corresponded to the time when populations naturally decline. The leafhopper threshold is based on leaf turn samples (threshold being ~15 leafhoppers per leaf). Preliminary research has shown that 1 leafhopper per leaf turn = 50 per sweep, so we were near the threshold in a couple of cases.

Spider Mites: Spider mite levels were overall lower in 2001 than in 2000. These conditions paralleled those in cotton and other area crops which had very low mite pressure during June and July. No mites were present in the fields until early August. At this time, due to the hot summer weather and following this date, to the irrigation cut-off in preparation for harvest, conditions for spider mites were ideal. Spider mites infestations increased to ~80% infested leaves in mid-August in field 96. The conventional treatment consistently had a higher mite infestation than the biorational treatment in both fields by ~10-25% (Fig. 10).

Damage Observations: Defoliation damage was minimal and constant during June. Damage increased in July and August. In field 99, the biorational treatment had slightly less damage than the conventional treatment (Fig. 11). Defoliation damage was less in field 96, and once the treatment regimes were established, there was slightly less damage in the conventional side compared with the biorational side.

Yields: Sugarbeet yields and sucrose contents were variable across treatments and across fields (Table 2). In one field, the biorational approach had a slight advantage in beet tonnage over the conventional approach and the opposite was true in the other field. Sucrose percentage was higher in the biorational field in both cases. The conventional treatment had a 0.6 t/A sucrose advantage over the biorational in field 96 whereas in field 99 the biorational had a ~0.4 t/a advantage. If one assumes a \$22 NSP per cwt. sugar, in field 96 the 1000+ lbs. of sugar in the conventional compared with the biorational treatment, clearly offset the \$30/A Success® application. However, in field 99, the biorational side had a lower input cost (~\$25/A) versus ~\$50/A for the conventional side and it also had a higher sugar yield (advantage of ~\$150/A).

Discussion

For this Fresno Co. study, pheromone trap catches and degree-day accumulations were generally in agreement. The armyworm flight had three peaks (generations) and the second and third generations were high. The bucket traps seemed to foretell the timing of larval infestations and were useful for determining the timing of treatment. Use of the wing traps was discontinued in 2001. Based on plant damage and beet yields, the biorational approach was equal to or better than the conventional treatment. However, the BAW pressure and spider mite levels were usually low in 2001. This contrasts with 2000 when neither strategy provided acceptable management of beet armyworm and/or the secondary pest complex.

Summary and Conclusions

The use of pheromone traps with degree day accumulations showed promise for beet armyworm. More effective reduced risk materials would aid this management program. Ideally, these materials would provide effective pest control and conserve populations of natural enemies which would reduce the build-up of secondary pests such as spider mites. A more refined treatment threshold would also be helpful. This would allow growers to concentrate treatments when they are most critically needed. This is important given the elevated costs of most of the reduced risk materials

and this information would facilitate adoption. Otherwise, “blanket” treatments of cheaper, traditional materials may continue to be the favored strategy.

Table 1. Insecticide use patterns on sugarbeets, Fresno and Imperial Counties, 1995-2000.

	1995	1996	1997	1998	1999	2000
<u>Fresno Co.</u>						
Pounds Active Ingredient Applied per Harvested Acre	1.5	2.0	3.8	2.6	2.8	1.6
Number of Acre Applications	1.8	2.5	4.8	3.1	3.6	2.3
Acre Applications - % Organophosphates	54.7	50.1	49.8	64.3	57.2	51.4
Acre Applications - % Carbamate	39.8	42.3	41.8	34.1	31.4	28.6
Acre Applications - % Pyrethroids	0	0	0.2	0.2	7.3	9.7
Acres Applications - % Biologicals	5.1	7.4	5.4	0.7	3.4	5.3
<u>Imperial Co.</u>						
Pounds Active Ingredient Applied per Harvested Acre	4.1	4.5	4.2	3.2	4.3	2.2
Number of Acre Applications	7.1	6.9	6.2	6.0	7.8	5.3
Acre Applications - % Organophosphates	75.1	80.0	78.2	67.7	63.0	64.2
Acre Applications - % Carbamate	11.7	16.5	19.9	15.8	17.2	13.1
Acre Applications - % Pyrethroids	13.2	0	0.0	16.2	17.5	20.4
Acre Applications - % Biologicals	0.0	0.0	0.4	0.3	1.4	3.4

Table 2. Yield results from PMA sugarbeet project, Fresno Co., 2001.

Field	Treatment	% Sugar	Tons Beets/A	Sugar (lbs)/A	Sugar/A (t)
#96	Biorational	14.16	33.16	9277.31	4.64
#96	Conventional	13.70	37.90	10381.87	5.19
#99	Biorational	13.72	35.28	9671.27	4.84
#99	Conventional	13.43	33.29	8930.69	4.47

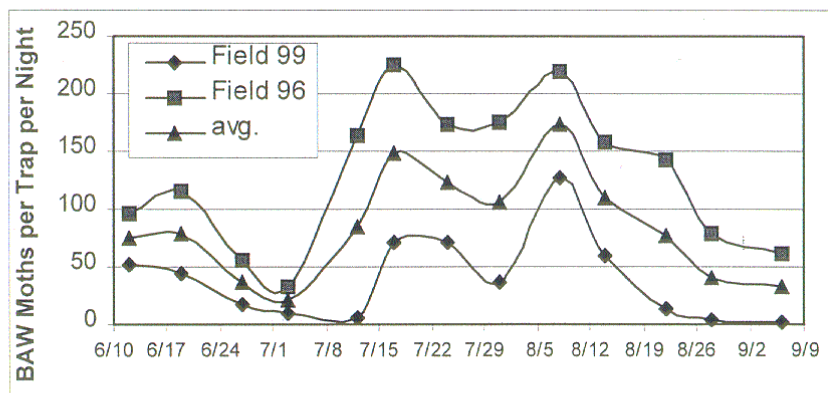


Figure 1. BAW moth flight as monitored with bucket pheromone traps in sugarbeet fields, Fresno Co., 2001

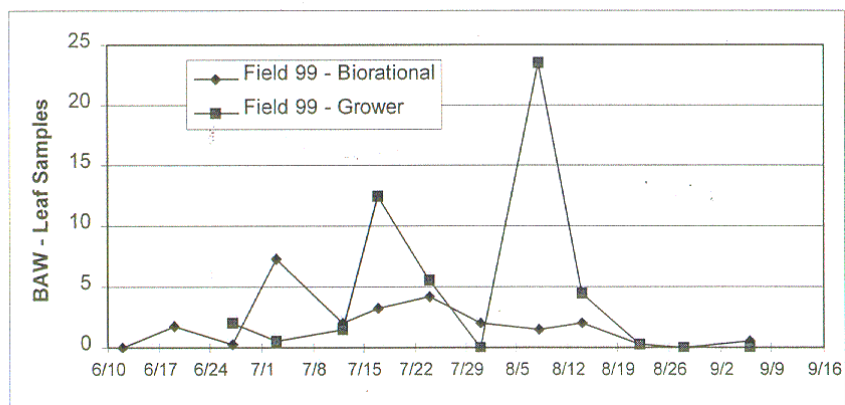


Figure 2. BAW larval populations from leaf samples (two sets of 20 leaves per treatment per date) in a sugarbeet field 99, Fresno Co., 2001.

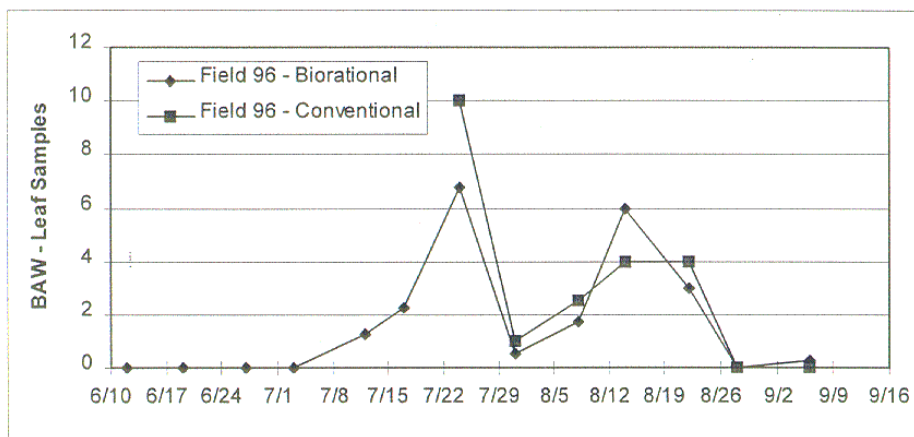


Figure 3. BAW larval populations from leaf samples (two sets of 20 leaves per treatment per date) in a sugarbeet field 96, Fresno Co. 2001.

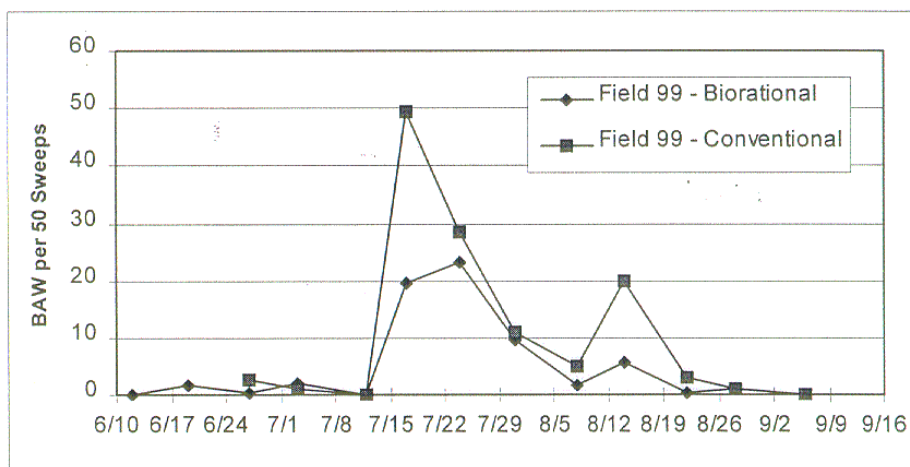


Figure 4. BAW larval populations from sweep net samples in a sugarbeet field 99, Fresno Co., 2001.

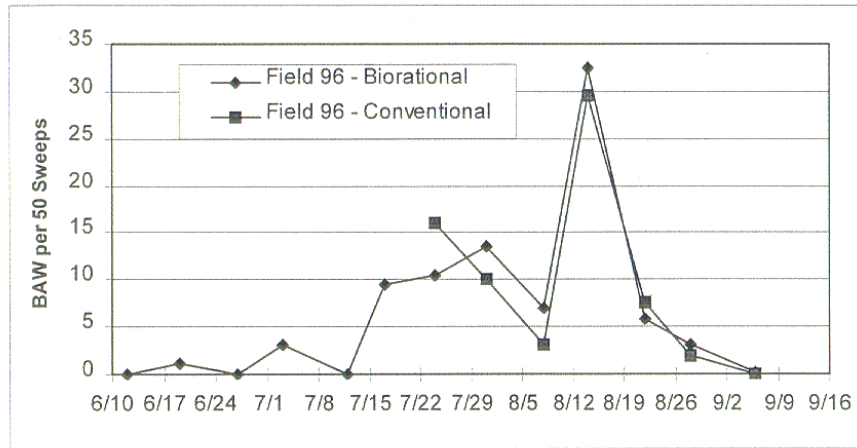


Figure 5. BAW larval populations from sweep net samples in a sugarbeet field 96, Fresno Co., 2001.

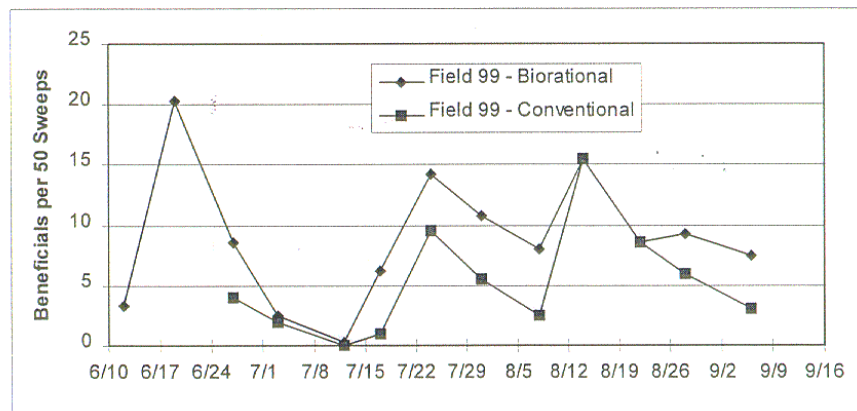


Figure 6. Populations of beneficials in sugarbeet field 99 under two different management schemes, Fresno Co., 2001.

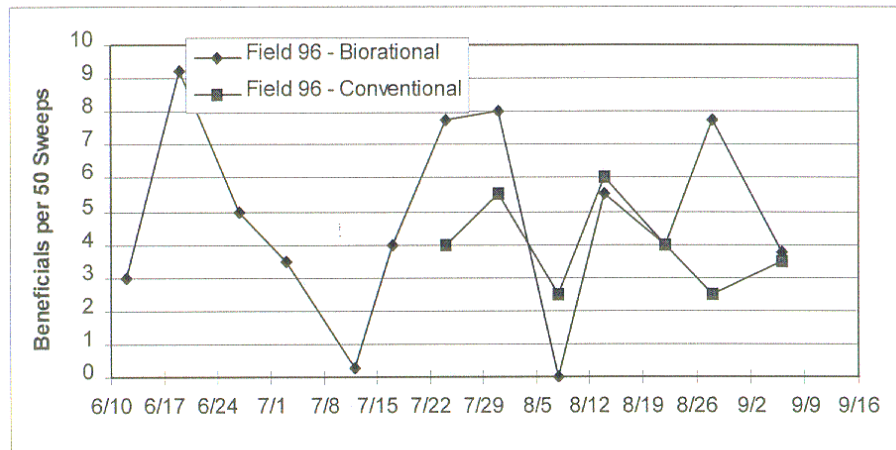


Figure 7. Populations of beneficials in sugarbeet field 96 under two different management schemes, Fresno Co., 2001..

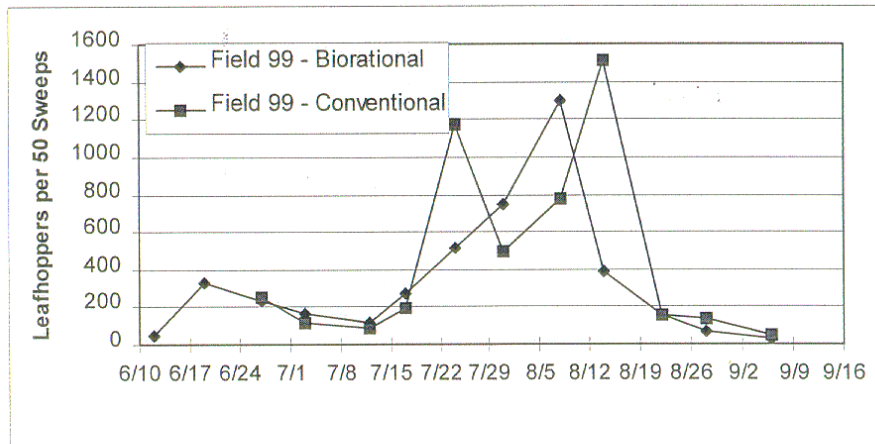


Figure 8. Levels of empasca leafhoppers in sugarbeet field 99 under two different management schemes, Fresno Co., 2001.

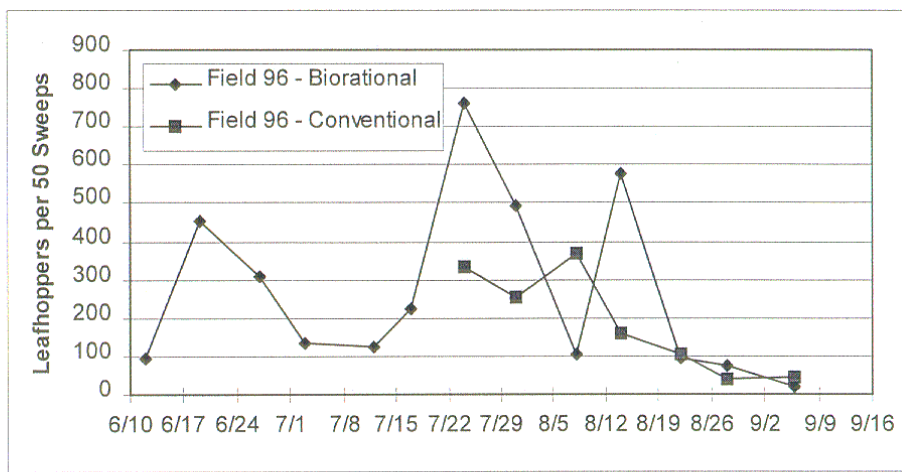


Figure 9. Levels of empasca leafhoppers in sugarbeet field 96 under two different management schemes, Fresno Co., 2001.

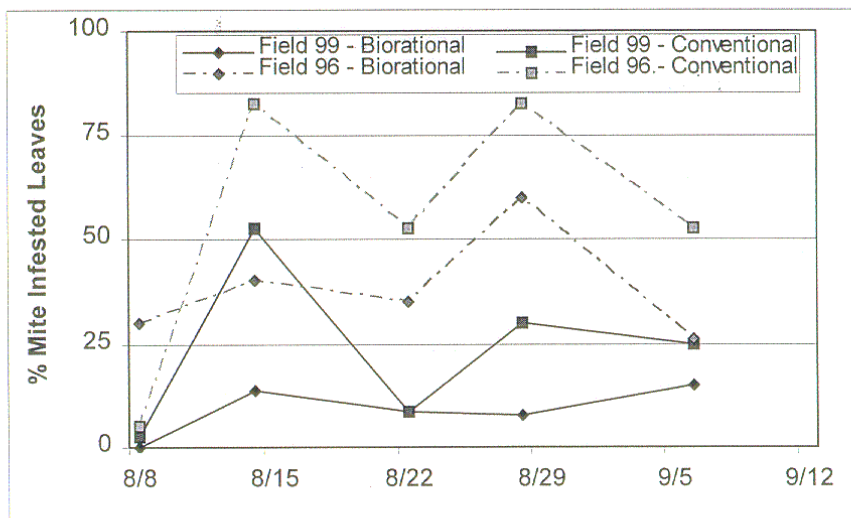


Figure 10. Percentage spider mite infested leaves for two sugarbeet fields with each field having two different management approaches, Fresno Co., 2001.

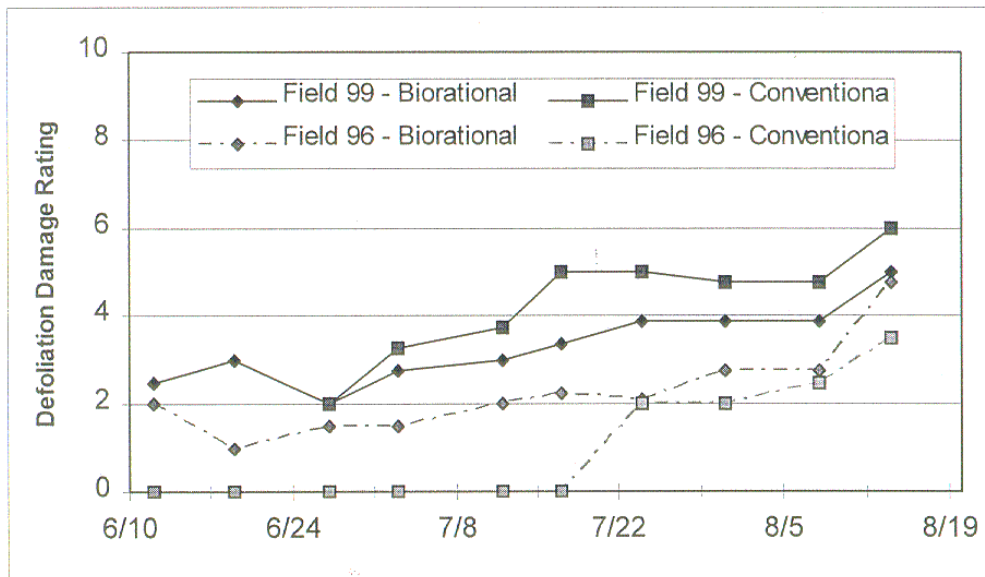


Figure 11. BAW defoliation damage ratings of two sugarbeet field under two management approaches, Fresno Co., 2001.

Reduced Risk Management of Insect Pests in Sugarbeets

Objective 2: Improving Sugarbeet Stands and Reducing Pesticide Use in the Imperial Valley:
Stephen Kaffka

Summary

The effects of different methods of protecting emerging sugarbeet seedlings were compared in a field trial in the Imperial Valley. Treatments included the current preferred growers' practice involving the use of an insecticide at planting combined with two or more post-emergence sprays for insect control, seed treatment with a systemic insecticide at two rates (imidicloprid or Gaucho®), and no control measures. Seedlings were counted four times until thinning. Pre-emergence pesticide applications resulted in significantly larger numbers of seedlings than when using untreated seeds. Gaucho® was as effective as the use of an organophosphate insecticide applied to soil at improving seedling emergence. Flea beetles were the principal cause of damage at emergence and are well controlled by Gaucho®, but it has no effect on armyworms. Armyworms caused little damage during the trial this year, but intensive pressure by flea beetles in the post-emergence period suggests that some post-emergence insect protection remains important in the Imperial Valley when fields are irrigated early in the fall. The amount may be reduced significantly, however, by using a seed treatment insecticide like imidicloprid.

Introduction

Sugarbeets are an important crop in the Imperial Valley, and once established, they grow well during the winter and spring months in the low desert. Planting takes place, however, during September and early October, when air and soil temperatures are above optimum, and the populations of insects preying on sugarbeet seedlings such as flea beetles and armyworms are large. Growers believe that control of insects on sugarbeet seedlings should begin as soon as seedlings appear and continue until late autumn. Management based on this assumption has been successful for many years, but the most commonly used materials for control (Lannate® (*methomyl*), Lorsban® (*chlorpyrifos*), and Diazinon®) are carbamate or organophosphate type compounds which currently are under review by US EPA for possible future restriction under the provisions of the Food Quality Protection Act. Diazinon was recently withdrawn voluntarily from the home garden market because of concerns about public exposure. Currently, there are no well-established alternatives to the use of these materials for sugarbeet seedling protection.

Methods

To demonstrate alternative seedling protection strategies and document loss to insects and other causes, a trial was conducted in the Imperial Valley near Brawley in a 22-acre sugarbeet field in the fall of 2001. Fifteen strips, each with 20 thirty inch rows a quarter mile long, were planted with Beta 4776R, a commonly planted variety in the area. All of the seed was from the same seed lot. Five different pre- and/or post-emergence treatments were applied (Table 1). Each treatment was

replicated three times. Emerging seedlings were counted in two twenty five foot long subplots in rows 7, 8, and 9 in each plot, at 10, 17, 22, and 28 days after irrigation. At the last date, seedling spacing was determined by measuring the distance between the first 100 seedlings in row 8 using the westernmost subplot. Also, the above-ground portions of 30 seedlings were collected from row 8 of each subplot, dried and weighed for comparison at thinning.

Each seedling was labeled with a small wooden stake at emergence. The stake was removed later if the seedling died and the cause of mortality was evaluated visually in the field. If a plant was chewed off or obviously damaged by insects, its loss was attributed to the insect damage category, if it was shriveled or desiccated, or a common seedling pathogen could be visually identified, it was classified in the shriveled or diseased category. If there was no seedling next to a stake, it was classified as missing. Using stakes allows for the identification of the majority of seedlings appearing. Those disappearing during the first three or four days from the start of emergence will not have been counted. The sum of the number appearing is *cumulative emergence*. The last count, just prior to thinning was considered to be the *final establishment*. Because the amount of seed planted is known, *pre-emergence losses* can be calculated by difference using observed cumulative emergence. The field was planted on September 12 and 13 using a Milton planter. The amount of seed remaining after planting the field was weighed to get an exact weight for the seed planted. In this trial, 70,000 seeds per acre were planted. This was divided by the known field area to get the seed population. We assume that planting occurred uniformly. The seeding rate used was a reduction from the previous year's trial. Irrigation was initiated on September 15th, the day following planting. The field had been pre-irrigated the preceding August. At the final count in the fall the distances between one hundred beets in one row per plot were measured. Data were analyzed using SAS v7.0 software.

Results

The results reported here are from the fall stand establishment period only (September through October, 2001). Yields will be measured in spring, 2002 and reported at that time. Planter problems occurred because of insufficient seed amounts when planting plots 1 to 4, which were planted last. In some of the plots, very few seedlings emerged, compared to the other two replications. Uniformity of seeding rates is an essential assumption for this trial. ANOVA tests indicated that replications were a highly significant factor (not shown), in contrast to previous years, when replications were not significant. Data were analyzed including all three replications, and then excluding the damaged replication. The relative performance of the treatments was the same in both analyses, but treatment differences were more significant if the first replication was excluded. Because uniform seeding rates could not be assumed for the plots 1 to 4, the first replication was omitted from this analysis.

Cumulative emergence. On average, a larger percentage of seeds resulted in sugarbeet seedlings in 2001 than in 2000, but a smaller amount than in 1999. In 1999, emergence reached 80% of seeds planted while in 2000, the best treatment resulted in approximately 50% emergence, and in 2001, approximately 70 % emergence was observed in the best treatments. Seedling survival was greatest

when pre-emergence insecticides were used (Table 2). There was no significant difference between the Grower's treatment using pre-emergence Lorsban® applied to the soil and seed treated with Gaucho® (Tables 2 and 3). No delay in emergence was observed for Gaucho® treated seeds (fig. 1). Significantly fewer seedlings emerged in the control treatment, lacking pre-emergence seedling protection (Tables 2 and 3). The two different Gaucho® rates were not significantly different, even though somewhat more seedlings emerged in the lower rate plots (fig. 1, Tables 2 and 3)

Pre-emergence losses are determined by difference (Table 2). Average pre-emergence losses ranged from approximately 30 % to 50 % of the seed planted. These losses include a small percentage (5 %) of non-viable seed. Other causes of pre-emergence loss include uneven seed beds and planter performance.

Establishment at thinning. The percentage of seeds resulting in established seedlings immediately prior to thinning (six to eight true leaves) is reported in Table 2. The average number of seedlings counted at each date is also presented in figure 2. There were no significant differences between the Growers and Gaucho® treatments, but the Control treatment had significantly fewer plants (Tables 2 and 3).

Cumulative mortality. There was very little post-emergence seedling loss up to thinning in all of the treatments, including the control treatments (Table 2, fig. 3). Flea beetle pressure was observed to be quite intense in the first two weeks of counting. Nonetheless almost all the seedlings emerging survived. Cumulative mortality increased only slowly with time.

Seedling growth. The dry weight (DW) of seedlings at thinning is compared in Fig. 4. The Growers treatment resulted in significantly larger seedlings than any of the other treatments. Seedling DW was less but similar for the two identical Gaucho® treatments (45g a.i. per unit) and declined further for the 20 g rate and for control treatments. Spraying the Gaucho®-treated seed at 12 days after irrigation once with Lorsban/diazinon did not significantly increase seedling DW compared to the equivalent treatment that was unsprayed. The lower Gaucho® rate (20 g a.i. per unit of seed) resulted in significantly smaller seedlings than the higher rate Gaucho® treatments.

Discussion.

Cumulative emergence and seedling establishment. Seedling numbers were not significantly different from each other if an insecticide was used but were significantly greater than the control treatment, in which only fungicides were used. Between approximately 50 % to 70 % of the seed planted resulted in stands in 2001. In the previous year 30 % to 50 % of the seed planted emerged, while in 1999, 50 % to 80% emerged. The most recent trial, like the one in 1999 was carried out in a pre-irrigated field. Results in these two years suggest that with average planter performance and the use of an insecticide at planting, between 65 % to 80 % of the seed planted can result in a useful sugarbeet plant in the Imperial Valley. This is a substantial improvement over the long term expectation of beet growers that only 50 % of the seed or less will result in a useful plant. The lower rate imidicloprid treatment (20 g a.i. per 100,000 seeds) performed as well as the higher rate

treatment for the second year in a row. Since performance at a lower rate is satisfactory, the lower rate should be used by growers, except perhaps for the earliest planted fields.

Plant protection. In the Imperial Valley, and other locations where pre-emergence losses are high, an insecticide applied with or to the seed appears necessary. For the third year in a row, pre-emergence losses were significantly greater when no insecticide was used at planting compared to the use of an insecticide. On average in 2001, approximately 20 % fewer seedlings appeared when no insecticide was used. Over the three years of this trial, pre-emergence losses varied from 20% to 40 % greater in the control treatment without an insecticide than in the other treatments. The significantly larger number of seedlings emerging in treatments including a pre-emergence insecticide in these three trials and in other trials conducted elsewhere in California leads to the inference that insect damage is occurring to seeds and emerging seedlings before they appear above ground.

Early seedling damage once again was due almost entirely to flea beetles. Armyworm larvae had not had time to develop and few were observed. Very few armyworm larvae were active in the plots during this trial and in the Imperial Valley generally this last autumn. From initial emergence onwards, flea beetles were present in the plots and damaged seedlings, even at the cotyledon stage. Based on visual estimation only, flea beetle pressure in plots seemed greater in 2001 than in any of the previous two years.

Gaucha[®] was very effective against flea beetles, and other cryptic insect pests affecting seedling emergence. At the lower rate (20 g a.i per unit), however, its effects against flea beetles diminished sooner. Post-emergence grazing by flea beetles resulted in smaller seedlings, but no increased mortality in this treatment. For the sake of seedling emergence, the lower rate of Gaucha[®] apparently is as effective as the higher rate, but its ability to protect seedlings lasts less long and may have to be combined with a post emergence treatment, depending on: 1) the amount of insect pressure observed, 2) how early in the season the field has been planted, and 3) the grower's tolerance for seedling damage. Early planted fields may require more post-emergence control than later planted fields when insects are abundant.

Costs of establishment.

The costs of treating plots, derived from the grower's records, are reported in Table 1. The most expensive treatment was the Grower's treatment, and the least expensive was the control. Applying Gaucha at 20 g a.i. per unit resulted in a cost of only \$14.00 per acre. This is a savings of \$38.30 per acre compared to the grower's treatment.

Increasing confidence in the potential success of stand establishment leads to lower establishment costs overall, even for conventional treatments. In each of the three years of this trial, costs for the stand establishment have declined. The growers have used fewer post emergence sprays, and reduced the amount of seed planted, saving themselves more than \$50.00 an acre. By using imidicloprid at low rates, and then observing the field for post-emergence insect damage, a grower

in the Imperial Valley should have the best chance to save money on stand establishment costs while insuring adequate plant stands.

Conclusions

1. Pre-emergence pesticide applications resulted in significantly larger numbers of seedlings than the control treatment without them.
2. Gaucho® applied to seeds was a satisfactory method of controlling pre-emergence seedling losses and resulted in adequate numbers of sugarbeet seedlings for a successful commercial crop. Flea beetles were the principal cause of damage at emergence and were well controlled by Gaucho® at the 45 g a.i. per unit of seed rate. The lower rate of Gaucho® resulted in similar numbers of seedlings compared to the growers treatment and the other higher rate treatments, but apparently did not reduce post emergence flea beetle damage to seedlings as well as in the higher rate plots. If the lower rate of Gaucho® is used, there will need to be field scouting for flea beetle and army worm damage after emergence, and a decision made whether additional control measures are needed.
3. Establishing a large percentage of seeds as seedlings saves growers money on seed costs and reduces the amount of pesticides applied, with imputed environmental benefits.
4. Some post-emergence insect protection remains important in the Imperial Valley when fields are irrigated early in the fall, but the amount may be reduced by using a seed treatment insecticide like Gaucho®.

Table 1
Treatments (2001)

Number	Description	Pesticides used	Timing (Days since first Irrig.)	Rates	Type of application	Cost (\$/ac)
1	Standard practice in the region (Growers')	Lorsban 15G	-2d	5.0 lb/ac	Soil applied with seed	10.00
		Lorsban 4E	12	1.33 pt/ac	Aerial	22.50
		Diazanone 4E		0.67 pt/ac		
		Trifol		0.27 pt/ac		
		Lorsban 4E + Diazanone 4E	22	1.14 pt/ac	Aerial	<u>19.30</u>
		Trifol		0.57 pt/ac		
				0.23 pt/ac		
						52.70 (total)
2	Seed applied systemic insecticide (Gaucho)	Imidicloprid (Gaucho)	Applied to seed prior to planting	45 g per 100,00 seeds; 31.5 g per acre*.	With seed	31.50 (total)
3	Seed applied systemic insecticide (Gaucho)	Imidicloprid (Gaucho)	Applied to seed prior to planting	20 g per 100,00 seeds; 14 g per acre.	With seed	14.00 (total)
4	No pre- or post-emergence treatments (Control)	none				0
5	Seed applied systemic insecticide (Gaucho)	Imidicloprid (Gaucho)	Applied to seed prior to planting	45 g per 100,00 seeds; 31.5 g per acre.	With seed	31.50
	One application of standard pesticide (1X)	Lorsban 4E	12	1.33 pt/ac	Aerial	22.50
				0.67 pt/ac		
				0.27 pt/ac		
						53.00 (total)

* Seed planted at the rate of 70,000 per acre. Betamix-Progress + Upbeet herbicides were applied on October 7.

Table 2
Seedling emergence and establishment at thinning

Treatment	Cumulative emergence (% of seed)	Cumulative post-emergence mortality (% of seed)	Cumulative post-emergence mortality (% of seedlings)	Established (% of seed)	Pre-emergence mortality (% of seed)
<i>Grower's</i>	68.3	1.3	1.9	67.0	31.7
<i>Imidicloprid@45g</i>	64.4	1.9	3.0	62.5	35.6
<i>Imidicloprid@20 g</i>	67.9	2.5	3.7	66.4	32.1
<i>Control</i>	51.7	0.7	1.4	51.0	48.3
<i>Imidicloprid@45g</i> <i>+ 1 aerial tmt.</i>	66.8	0.7	1.1	66.1	33.2
<i>LSD_(0.05)</i>	3.1	0.75		3.2	

Imperial Valley, (fall 2001). Data collected at 28 days after initial irrigation. Includes 5.7% non viable seed.

Table 3

Treatment contrasts (Days since initial irrigation = 28, final count)

Treatments*	Variables	SS	F	p =
<i>Growers vs Gaucho</i>	Cumulative emergence	126.56	2.13	0.1456
	Number established	145.00	2.24	0.1356
	Cumulative mortality	0.627	0.18	0.6726
<i>Gaucho @ 45g vs Gaucho @ 20 g</i>	Cumulative emergence	287.04	4.83	0.0289
	Number established	110.0	2.33	0.131
	Cumulative mortality	3.760	1.07	0.3010
<i>Pre-emergence insecticide vs control (1+2 vs 4)</i>	Cumulative emergence	6854.25	115.4	<.0001
	Number established	6040.83	93.45	<0.0001
	Cumulative mortality	25.68	7.34	0.0073

*See Table 1 for treatment descriptions

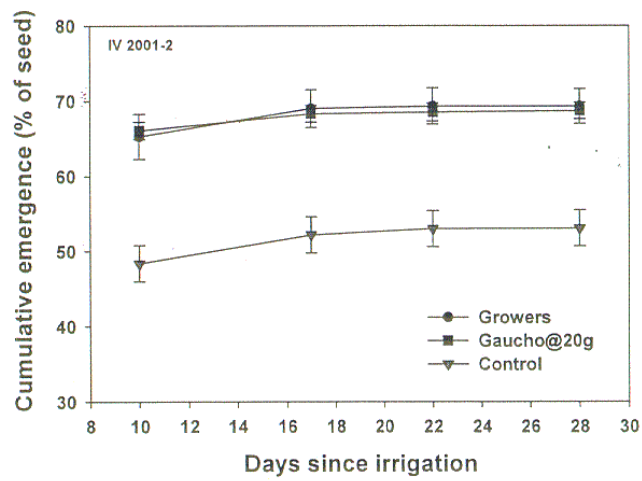
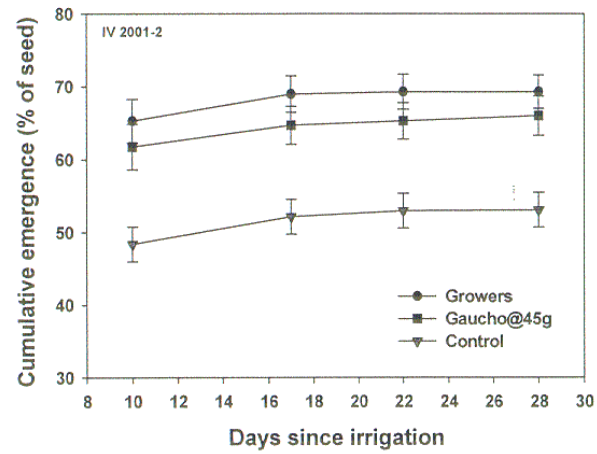


Fig 1. Cumulative emergence comparisons, for the two Gaucho rates applied and the Growers and Control treatments. Error bars are standard errors in all figures.

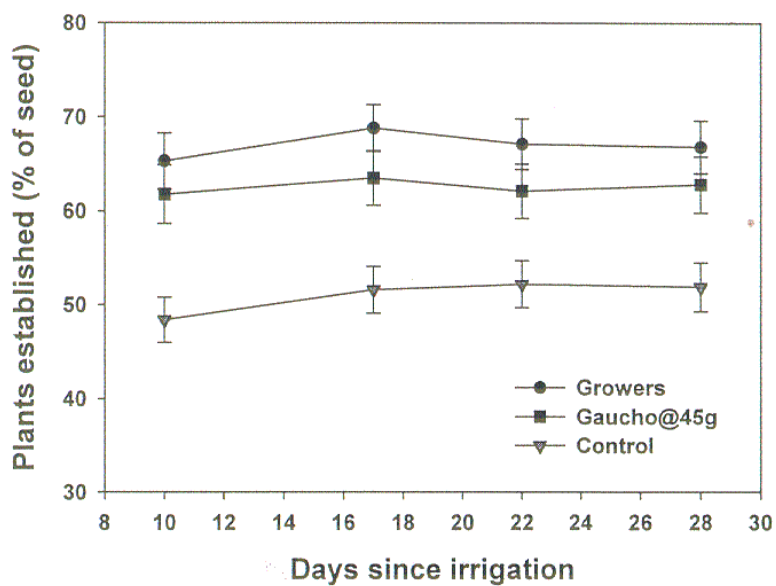


Fig. 2. Established plants. Percent of seed sown. Imperial Valley, 2001.

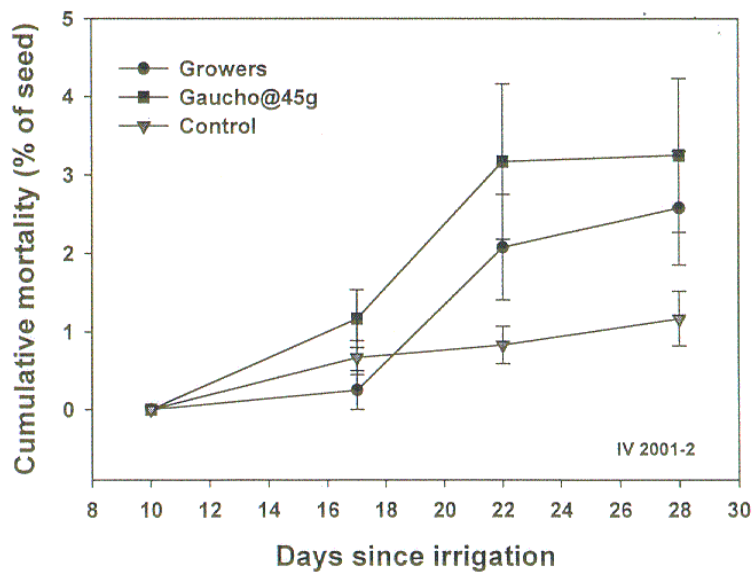


Fig. 3. Cumulative mortality. Percent of seed sown. Imperial Valley, 2001.

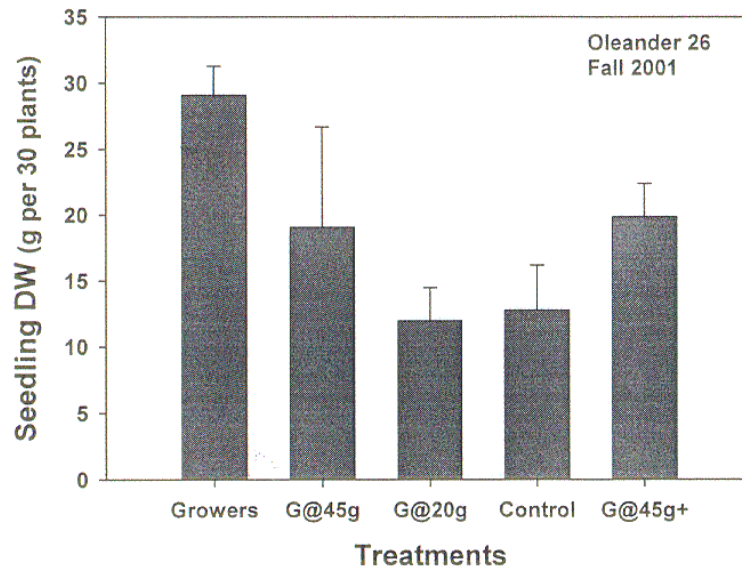


Fig. 4. Seedling dry weights, g per 30 seedlings. Imperial Valley, 2001.

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APPENDIX A

ARTICLES AND PRESENTATIONS FROM PMA PROJECT

- Godfrey, Larry, Haviland, David. "Development of Reduced Risk Management of Sugarbeet Armyworm," *The California SUGAR BEET* (California Beet Growers Association's 2001 Annual Report).
- Kaffka, Stephen, Babb, Tom, Godfrey, Larry, Terini, Tom. "Alternatives to Current Stand Establishment Practices in the Imperial Valley, *The California SUGAR BEET* (California Beet Growers Association's 2001 Annual Report.)
- Kaffka, Stephen. Results presentation at meeting of American Society of Sugarbeet Technologists. March 2001, Vancouver, British Columbia, Canada.
- Kaffka, Stephen, Goodwin, Ben. Results presentation at California Beet Growers Association District No. 9 Annual Meeting (Imperial Valley). October 2001, Brawley, California. "Sugarbeet Pest Management Alliance: Reduced Risk Management of Insects in Sugarbeets."
- Kaffka, Stephen, Goodwin, Ben. Results presentation at California Beet Growers Association District No. 10 Annual Meeting (Kern County). November 2001, Bakersfield, California. "Sugarbeet Pest Management Alliance: Reduced Risk Management of Insects in Sugarbeets."
- Godfrey, Larry, Kaffka, Stephen, Goodwin, Ben. Results presentation at California Beet Growers Association District N. 6 Annual Meeting (South San Joaquin Valley). November 2001, Fresno, California. "Sugarbeet Pest Management Alliance: Reduced Risk Management of Insects in Sugarbeets."
- Godfrey, Larry. Project poster presentation at the meetings of the Entomological Society of America. June 2001 (area meeting); December 2001 (national meeting).
- Godfrey, Larry, Kaffka, Stephen, Goodwin, Ben. Results discussed at the U.C. Sugarbeet Work Group Meeting. January 2002, U.C. Davis, Davis, California.
- Kaffka, Stephen. Results presentation at meeting of Institute of Sugarbeet Research. February 2002, Brussels, Belgium.
- Kaffka, Stephen. Results presentation at meeting of sugarbeet researchers. February 2002, Bonn, Germany.
- Kaffka, Stephen. Results presentation at Spreckels Sugar Company's Production Conference. March 2002, Los Banos, California. "Sugarbeet Pest Management Alliance: Reduced Risk Management of Insects in Sugarbeets."
- Godfrey, Larry, Kaffka, Stephen. Project poster presentation at CAL EPA Day, Pest Management Alliance Update Meeting. March 2002, Sacramento, California.